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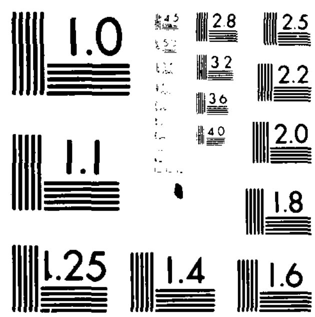

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ASSESSMENT OF AQUIFER IMPACTS OF MX GROUND-WATER WITHDRAWALS IN DRY LAKE VALLEY, NEVADA

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office
Norton Air Force Base, California 92409

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Impacts caused by MX ground water withdrawals in Dry Lake Valley, Nevada were estimated by a mathematical model. Results indicate that residual drawdown at a distance of one mile from each of the six pumping wells was less than 2.7 feet 8.3 years after pumping for construction.

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FOREWORD

This report presents the impacts of short-term, high rate and long-term, low rate ground-water withdrawals from six potential U.S. Air Force MX missile project wells on the existing water resources in Dry Lake Valley, Nevada. The computer program which was used to simulate the unconfined ground-water flow system is explained in "Finite-Difference Model for Aquifer Simulation in Two Dimensions" developed by Trescott and others (1976) of the U.S. Geological Survey. The ground-water aquifer was assumed homogeneous. Uniform values of aquifer transmissivity and storage coefficient derived by calibrating field measured data from four existing observation wells were used in the analysis. The potential for subsidence associated with pore pressure decline from ground-water withdrawal was also examined based on boring tests of aquifer matrix.

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1.0 INTRODUCTION

This report summarizes the results of the potential impacts of ground-water withdrawal on the existing water resources in Dry Lake Valley. The ground-water withdrawal system was analyzed by a detailed, two-dimensional numerical model that was based on the field measured physical characteristics of the flow media. This report will provide hydrogeological data necessary for planning the necessary ground-water withdrawals for the proposed MX program.

1.1 STUDY PURPOSES

The purposes of the numerical modeling study were to (1) evaluate the overall ground-water aquifer flow within the hydrologic regime of the Dry Lake/Muleshoe Valley basin, (2) investigate and identify the potential impacts of the proposed U.S. Air Force MX missile project ground-water withdrawals on the existing water resources, (3) provide information to optimize the ground-water system management that will minimize the ground-water withdrawal impacts, and (4) evaluate the potential land subsidence associated with pore pressure decline resulting from proposed MX ground-water withdrawal.

1.2 SCOPE OF WORK

The scope of this study included field investigations, pumping data measurements, model calibration of aquifer parameters, and numerical model simulation of potential impacts.

The numerical model of Dry Lake Valley has two major components. First, the ground-water hydrology of the valley-fill aquifers

of Dry Lake and Muleshoe valleys were represented by a numerical model. The aquifer recharge and discharge were estimated and distributed throughout the valleys according to information analyzed by Ertec and previous hydrogeologic investigations. Second, the ground-water flow in the aquifers was simulated by the two-dimensional finite-difference model of Trescott Pinder and Larson (1976) with a direct solution algorithm added by Larson based on work by Price and Coats (1973). Additional modifications made during this study made various fluxes, such as evapotranspiration, implicit functions of head. Four existing observation wells were utilized in the calibration of the model and six potential MX wells were represented in the studies of impact. In this report, the combination of recharge, discharge, aquifer characterization, finite-difference model, and represented wells are collectively called the model of Dry Lake Valley or, simply, the "model."

Calibration of the model determined the best estimate for aquifer transmissivity from water levels measured at four observation wells in the absence of significant pumping in the valley. The best estimate was the value of transmissivity that caused the model to compute a potentiometric surface that best fitted the observed water levels. The measure of best fit was the minimum sum of squares of the differences between the observed levels and the calculated elevations of the potentiometric surface at the location of the observation wells.

Values of storage coefficient obtained from aquifer pumping tests provided only a lower limit because the pumping test could

not be run long enough to provide a true value. On the basis of the aquifer material and professional judgment, the storage coefficient was increased from the lower limit to the value used in the model.

The simulation results were used to assess the impacts of pumping from MX wells during the construction of MX facilities.

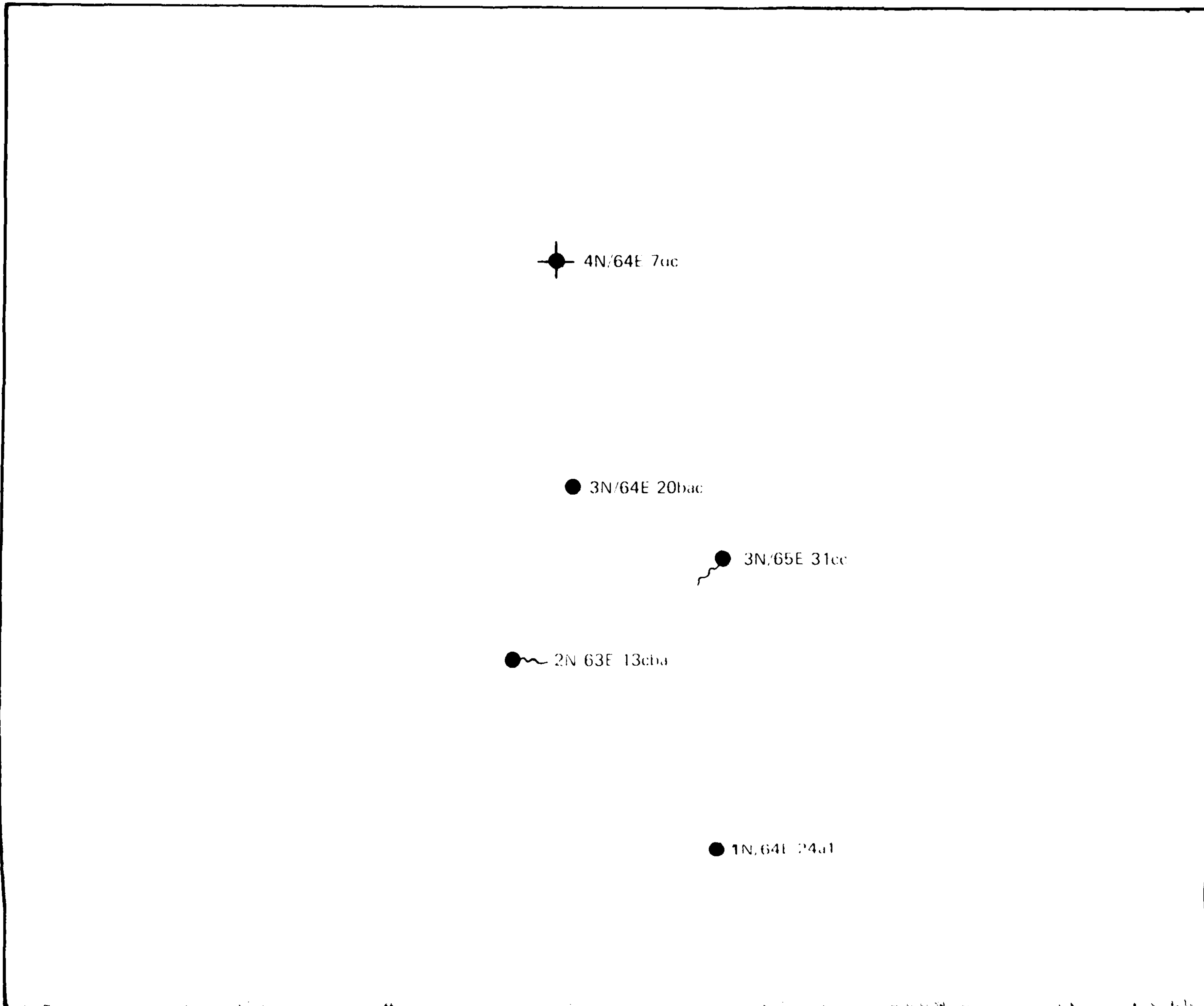
2.0 AQUIFER DESCRIPTION

2.1 SETTING

Dry Lake Valley is a north-trending basin in Lincoln County, Nevada (Figure 1). The valley is topographically open with Muleshoe Valley to the north; it is separated from Delamar Valley to the south by a low alluvial divide. Muleshoe and Dry Lake valleys are considered one hydrologic basin by the Nevada State Engineer (1971). Dry Lake Valley is 38 miles (61 km) long, 21 miles (34 km) wide at its widest point, and has an area of approximately 700 mi^2 (1812 km^2). The average valley floor elevation is 4700 feet (1433 m) above Mean Sea Level (MSL). The valley is bordered by the North Pahroc Range on the west and the Burnt Springs, Highland, and Bristol ranges on the east. The mountain crests range in elevation from about 7000 feet (2134 m) to over 9000 feet (2743 m) MSL.

The mountains bordering Dry Lake Valley to the west contain ash flow tuffs and clastic rocks of Tertiary age with carbonate and clastic rocks of Paleozoic age. The mountains to the east contain carbonate and clastic rocks of Paleozoic age with minor amounts of ash flow tuffs and clastic rocks of Tertiary age (Stewart and Carlson, 1978).

There is no perennial streamflow in Dry Lake Valley, but there is some ephemeral surface-water inflow from Muleshoe Valley. Total runoff from the mountains at the apex of the alluvial fans for the combined Dry Lake, Muleshoe, and Delamar valleys hydrographic areas is estimated to be 9000 acre-ft/yr (11.1 hm^3/yr)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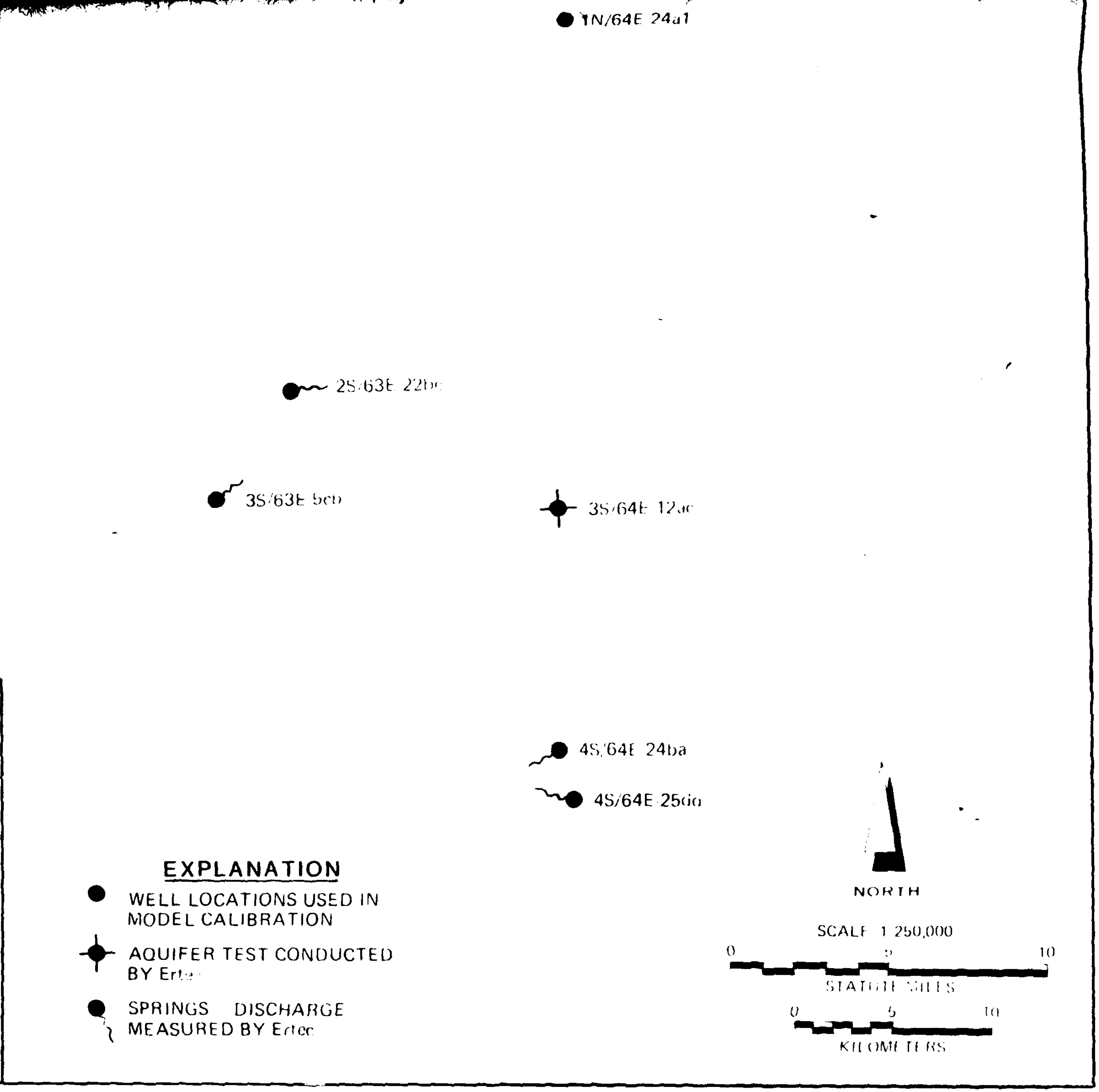

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MAP OF DRY LAKE VALLEY

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FIGURE 1

(State of Nevada, 1971). Small springs in or near the base of the surrounding mountains issue from the clastic rocks of Paleozoic age and the volcanic and clastic rocks of Tertiary age. Six springs discharged from 0.5 to 3 gpm (0.03 to 0.19 l/s) when measured in 1979 and 1980 by Ertec personnel.

2.2 GEOHYDROLOGY

The thickness of the valley-fill aquifer in Dry Lake Valley is estimated, from the results of a gravity survey to be 10,000 feet (3048 m) thick in the central part of the valley (FN-TR-33-DL). The valley-fill aquifer is composed of alluvial fan, fluvial, playa, and lacustrine deposits (FN-TR-26-E). Eakin (1963) describes the valley-fill sediments as clay, silt, sand, and gravel of Tertiary to Quaternary age deposited under sub-aerial and lacustrine conditions.

The Dry Lake Valley basin is a hydrologically open system with underflow to the south or southwest through the carbonates of Paleozoic age (Eakin, 1963). Total discharge by underflow is estimated to be 4800 acre-ft/yr (5.9 hm^3/yr) (Eakin, 1963). The hydraulic gradient is southward at 16 feet/mile (3 m/km) from central Dry Lake Valley to central Delamar Valley. The potentiometric surface ranges in elevation from 5000 feet (1524 m) in the north to 4200 feet (1280 m) in the south based on the regional potentiometric map. The depth to ground water in Dry Lake Valley is in excess of 300 feet (91 m).

2.3 GROUND-WATER HYDROLOGY

The general movement of the ground water was determined from potentiometric surface elevations from existing wells and the geology (playa location). In the playa area, the potentiometric gradient to the south is much flatter than in the northern part of the valley. At the south end of the valley (just south of the playa), the gravity survey indicates that bedrock rises to within 1000 feet (305 m) of the surface making the aquifer much shallower than in the central part of the valley. From these indications, the discharge from the valley-fill aquifer is primarily into the regional carbonates with a small amount through the valley fill to Delamar Valley.

Ground-water recharge is from the infiltration of precipitation in stream channels and surface runoff on the alluvial fans. The average annual recharge for Dry Lake/Muleshoe valleys is estimated to be 4800 acre-ft/yr (5.9 hm^3/yr) (Eakin, 1963). Of this amount, approximately 2100 acre-ft/yr (2.6 hm^3/yr) is derived from precipitation in the mountains around Muleshoe Valley with the remainder from sources within Dry Lake. Table 1 provides a summary water budget for Dry Lake Valley.

2.4 SURFACE-WATER HYDROLOGY

Surface-water use, primarily for stock watering, is estimated to be 21 acre-ft/yr (0.03 hm^3/yr) in Dry Lake Valley. Evapotranspiration and water discharged by wells is less than a few hundred acre-feet per year (Eakin, 1963). Evapotranspiration of ground water occurs only in limited areas near small springs

TABLE 1 - WATER BUDGET FOR DRY LAKE VALLEY

	acre-ft/yr	hm^3/yr
Discharge from Muleshoe Valley to Dry Lake Valley	2100	2.6
Recharge to Dry Lake Valley	2700	3.3
Evapotranspiration and Use of Ground-Water in Dry Lake Valley	Negligible	---
Discharge from Dry Lake Valley	4800	5.9

that are from perched water bodies above the primary valley-fill aquifer.

Because Dry Lake and Muleshoe valleys are considered one hydrologic basin, they are also considered one basin for the numerical model. Therefore, the discussion on the numerical model includes both the Dry Lake and the Muleshoe valleys.

3.0 THE GROUND-WATER SYSTEM AND MODEL REPRESENTATION

3.1 GROUND-WATER FLOW BOUNDARIES

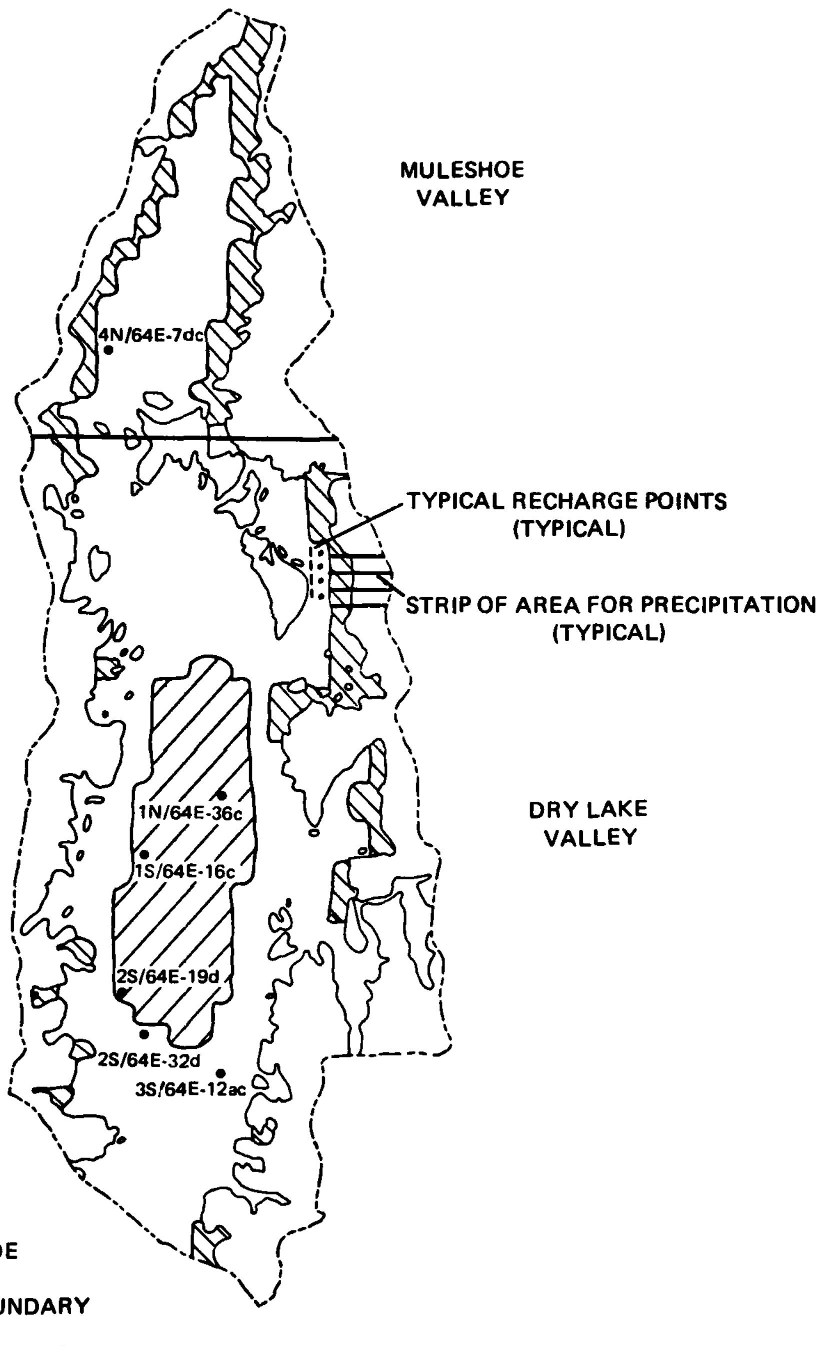
The perimeter of the Dry Lake/Muleshoe Valley was treated as a zero-flux boundary in the numerical model. The actual rock types at the boundaries have relatively low hydraulic conductivity around Muleshoe Valley in the north and in the Bristol and Highland Peak ranges on the east side of Dry Lake Valley. In the mountains of the western boundary, the rock types are relatively impermeable clastic and volcanic rock. Although not impermeable, the southern boundary of the valley-fill aquifer in Dry Lake Valley was modeled as zero-flow because it was assumed that the outflow in that part of the valley is through leakage to the underlying carbonates.

Discharge to the regional carbonate system was specified in the central part of Dry Lake Valley, as shown in Figure 2. The discharge rate equals the recharge rate of 4800 acre-ft/yr (5.9 hm3/yr).

3.2 GROUND-WATER RECHARGE

The recharge value used in the model was 4800 acre-ft/yr (5.9 hm^3/yr) (Eakin, 1963). The areal recharge rates were derived using Eakin's (1963) elevation, precipitation, and percent infiltration distributions. The data used are presented in Table 2. The areas where recharge is assumed to occur are shown in Figure 2.

In the model, the recharge from each area in Figure 2 was applied at recharge points on the valley boundary of that area



EXPLANATION

- TOPOGRAPHIC DIVIDE
- ROCK-NONROCK BOUNDARY
- MODELED RECHARGE AREA
- MODELED DISCHARGE AREA
- LOCATIONS OF SIMULATED MX PRODUCTION WELLS
- BOUNDARY BETWEEN DRY LAKE AND MULESHOE VALLEY

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RECHARGE AND DISCHARGE AREAS USED IN DRY LAKE-MULESHOE VALLEY MODEL

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FIGURE 2

TABLE 2 - RECHARGE FROM PRECIPITATION *

PRECIPITATION ZONE (altitude in feet)	ESTIMATED ANNUAL RANGE (inches)	PRECIPITATION AVERAGE (inches)	PERCENT TO RECHARGE
Below 6000	<8		0
6000 - 7000	8 - 12	10	3
7000 - 8000	12 - 15	13.5	7
8000 - 9000	15 - 20	17.5	15
Above 9000	>20	21	25

* After Eakin (1963)

(Figure 2). The area between the recharge points and the drainage boundary was divided into strips, one for each recharge point. Using the average elevation on each strip, the average precipitation and percent of recharge for the strip were obtained (Table 2). Multiplication of the average recharge and the area of the strip provided the volume of recharge to be applied at the corresponding point. To make the total recharge equal to Eakin's estimate, the recharge estimates were adjusted proportionately so that the total for all points equalled 4800 acre-ft/yr (5.9 hm^3/yr).

3.3 GROUND-WATER DISCHARGE

No discharges other than underflow were considered in the model. Discharge by evapotranspiration of ground-water from the valley-fill aquifer does not occur because the depth to water is greater than 300 feet (91 m) in Dry Lake Valley and greater than 250 feet (76 m) in Muleshoe Valley. Phreatophytes use very little water, if any, at depths greater than 50 feet (15 m) below land surface. Because current ground-water use is minor in Dry Lake/Muleshoe Valley, no existing pumping was included in the model.

3.4 ESTIMATED AQUIFER PARAMETERS

To obtain data on the magnitude and variation of aquifer parameters in Dry Lake and Muleshoe valleys, Ertec installed one test well and accompanying observation well in each valley. The locations of the test wells are shown in Figure 1 as T4N, R64E, Section 7dc (4N/64E-7dc) and T3S, R64E, Section 12ac (3S/64E-12ac). Aquifer tests were conducted at each test well. From

the tests in Dry Lake Valley, the most reliable estimate of transmissivity was 3300 ft^2/day (307 m^2/day), while the most reliable, minimum estimate of specific yield was 0.012. From tests in Muleshoe Valley, the most reliable estimates of transmissivity and specific yield were 39 ft^2/day (3.6 m^2/day) and 6.2×10^{-4}, respectively.

Because the aquifer is unconfined and the aquifer test was of limited duration, the values of specific yield obtained from the aquifer tests indicate lower limits rather than the actual values. If the tests could have been continued for a longer duration, the values of specific yield would have been significantly greater. The aquifer is composed of medium to coarse-grained sand and as such a conservative value of 0.05 was selected for use in the model simulation runs for MX impacts.

The specific yield was selected on the basis of aquifer tests in both Dry Lake and Muleshoe valleys and professional judgment. The transmissivity was determined by calibration runs with the model and checked against values from aquifer tests.

3.5 CALIBRATION

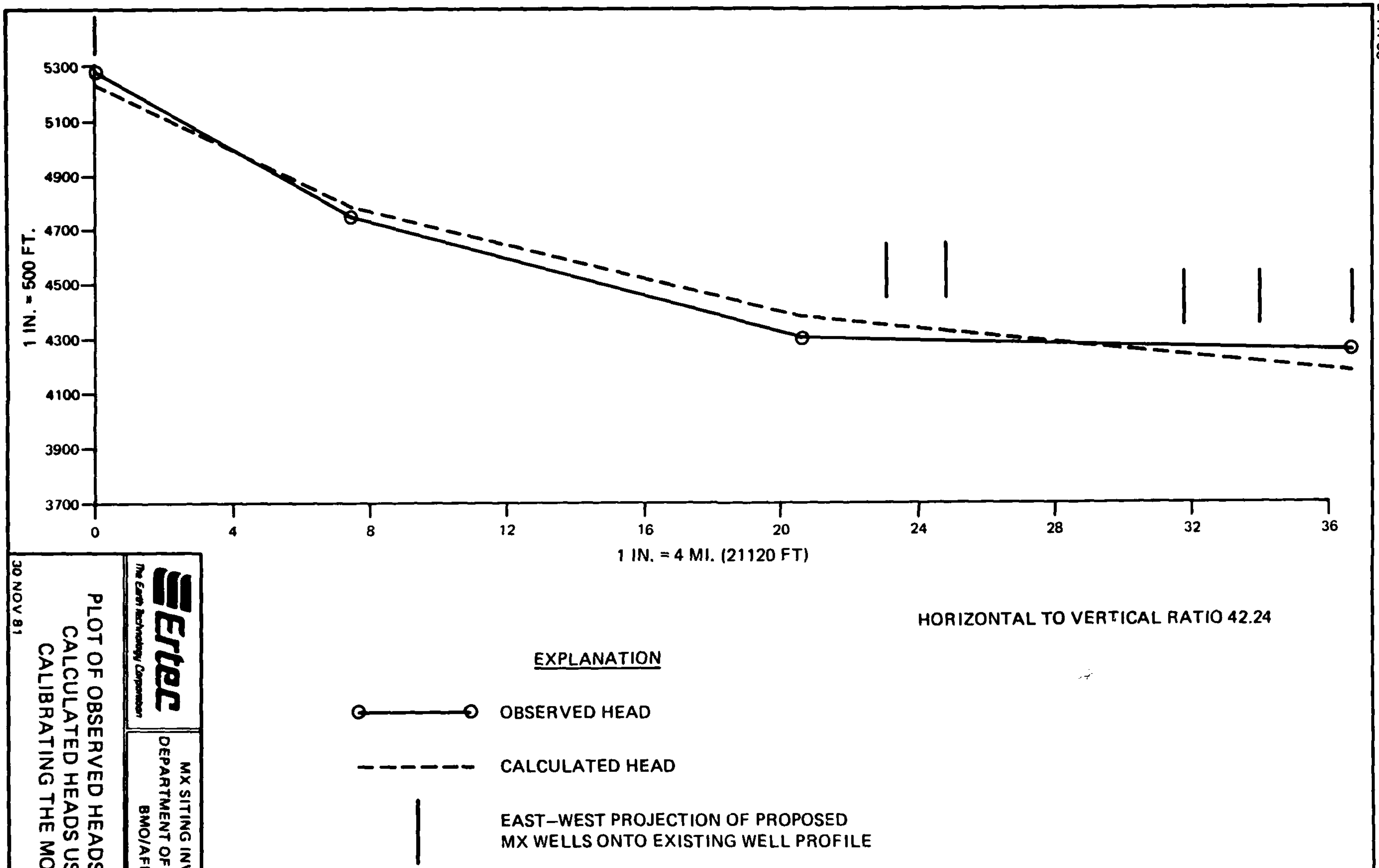
Calibration of the model refers to the process of determining those values of the model's parameters that cause the model to best reproduce observed elevations of the potentiometric surface. The aquifer recharge, discharge, and boundary conditions used in the model for the calibration must be equivalent to those that produced the observed elevations. A complete set of data are implied. That is, the recharge, discharge, boundary

conditions, and potentiometric surface are all supposed to be known, leaving only the model parameters to be determined.

For calibration, the Dry Lake Valley model was used to calculate the potentiometric surface corresponding to the described recharge and discharge conditions with no ground-water withdrawal from any wells. The available data on the potentiometric surface consisted of observed water surface elevations at the four wells shown in Figure 1. The observed elevations are plotted in Figure 3 and listed in Table 3. For recharge and discharge, the available data consisted of the estimated magnitudes and spatial distribution discussed in Sections 3.2 and 3.3. The available boundary condition data include the assumptions discussed in Section 3.1. In addition to these data, aquifer tests and descriptive information about the geology and material of the valley fill are also included.

From the geology of the valleys and the two aquifer tests, it is clear that the aquifer transmissivity could vary significantly throughout the valley. However, it is also clear that with the data available it would not be possible to identify in any detail transmissivities that varied throughout the model. Instead, a single value was used to define the average value of transmissivity in the aquifer system.

Although a transient analysis was not used, the computations did not correspond to a simple steady state in which all fluxes and potentiometric elevations throughout the aquifer were constant and in balance. If such a state existed, there were no



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PLOT OF OBSERVED HEADS VERSUS CALCULATED HEADS USED IN CALIBRATING THE MODEL

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FIGURE 3

TABLE 3 - ELEVATION OF MEASURED AND COMPUTED POTENTIOMETRIC SURFACE AT EXISTING OBSERVATION WELLS

LOCATION	ACTUAL POTENTIOMETRIC ELEVATION (feet)	MODELED POTENTIOMETRIC ELEVATION (feet)
4N/64E-7dc	5270	5229
3N/64E-20bac	4750	4786
1N/64E-24al	4302	4397
3S/64E-12ac	4262	4172

historical data corresponding to it. Instead, the fluxes and elevations were assumed to vary continuously. The model was developed to use time-averaged values of these variations. That is, values of fluxes and elevations are averaged over many seasons.

An iterative search for the value of transmissivity was used for the model. In each iteration, a trial value produced a potentiometric surface that was calculated by the model. The surface was made to pass through one point where the elevation could be set at any arbitrary value called the intercept. The shape and elevation of the whole surface and the difference between the calculated and observed elevations of the surface at the observation wells are functions of the transmissivity and the intercept.

The sum of the squares of these differences was used as a measure of how well the calculated surface matched the observed elevations. By nonlinear, least-squares analyses, the search led to the value of transmissivity corresponding to the minimum sum of squares. This value of transmissivity that produced the best fit during the calibration of the model is 1300 ft^2/day (119 m^2/day) and was selected for the study of MX pumping impacts. This regional value is representative of the aquifer as a whole, as well as it is presently known, and is also sufficiently large to cause little error in drawdown estimates due to its uncertainty (i.e., insensitivity to T).

4.0 MX ASSESSMENTS

4.1 INTRODUCTION

The primary impacts of extractions from MX wells are the drawdown that occurs during pumping from the wells and the time required for water levels to recover after the pumping ceases. These impacts can be distinguished between those affecting the total alluvial aquifer and those occuring near the MX wells. Aquifer impacts are of concern for springs and the operation of non-MX wells while near-well impacts are of concern for the operation of the MX wells. Because it is proposed to site all MX wells at least 1 mile (1.6 km) from all springs and non-MX wells, drawdowns and recovery occurring 1 mile from the well are the maximum values of the alluvial aquifer impacts. Those effects occurring within a distance of 1 mile are considered near-well impacts.

4.2 METHOD OF SUPERPOSITION

The analysis of the impact of pumping MX wells must consider recharge, discharge to underflow, and pumping from MX wells. Because of the basic nature of the ground-water system, the analysis can be divided into two separate parts, and the results of both parts can be combined. One part includes drawdown produced only by MX wells pumping with no recharge or discharge. The other part of the analysis considers the inflow (recharge) and outflow (discharge) boundary conditions. By assuming that the MX withdrawal is totally supplied by aquifer storage, the outflow is considered to be equal to the inflow. If the MX

withdrawal is large relative to aquifer storage, a portion of the natural outflow may contribute to the MX withdrawal through the reduction of leakage to the regional carbonate system. The first part of the analysis was performed using the numerical model. The second part is the natural fluctuation of ground-water levels caused by existing stresses. The combination of the results of both parts provides the assessment of the impact. Division of an analysis into separate parts and addition of the separate results to obtain the total result is usually called the method of superposition.

The ground-water flow equation can be written as

$$\nabla \cdot (T \cdot \nabla h) + q + \frac{K}{b}(h_c - h) = S \frac{\partial h}{\partial t} \qquad (1)$$

in which

- T = transmissivity tensor ($L^2 T^{-1}$),
- h = hydraulic head (L),
- q = volumetric flux of recharge or withdrawal per unit surface area of the aquifer (LT^{-1}),
- K = vertical hydraulic conductivity (LT^{-1}),
- b = saturated thickness of the confining layer (L),
- h_c = hydraulic head in the underlying carbonate aquifer, on the other side of the confining bed (L),
- S = storage coefficient (dimensionless),
- t = time (T)

The term, $\frac{K}{b}(h_c - h)$, represents the seepage flow between the adjacent aquifers.

In the application of the method of superposition, by letting $h = h + s_{mx}$, and $q = q + q_{mx}$; where s_{mx} is the drawdown due to

MX withdrawal and q_{mx} is the MX withdrawals, the flow equation becomes:

$$\nabla \cdot (T \cdot \nabla [h + s_{mx}]) + (q + q_{mx}) + \frac{K}{b}(h_c - h - s_{mx}) = S \frac{\partial (h + s_{mx})}{\partial t} \tag{2}$$

which is equal to the summation of the following two equations,

$$\nabla \cdot (T \cdot \nabla h) + q + \frac{K}{b} (h_c - h) = S \frac{\partial h}{\partial t} \tag{3}$$

and

$$\nabla \cdot (T \cdot \nabla s_{mx}) + q_{mx} - \frac{K}{b} (s_{mx} - h_c) = S \frac{\partial s_{mx}}{\partial t} \tag{4}$$

if $h_c \neq 0$.

Equation (3) is the existing ground-water flow conditions, and equation (4) represents the superposition model for the MX ground-water withdrawals. Equation (4) was solved with a numerical model and equation (3) represents existing conditions. Results from both equations are combined to obtain the solution for the MX ground-water withdrawals.

4.3 MODEL ANALYSIS

In the analysis by superposition, the model was used to calculate drawdowns for pumping from MX wells for six years followed by recovery for 30 years. During the 36 years, there is no other recharge or discharge, and all of the MX withdrawal comes from storage.

In the model, there were six proposed MX wells located as shown in Figure 2 and Table 4. The pumping rates were made equal to the water requirements during the period of MX construction.

TABLE 4 - WATER DEMAND ESTIMATES USED IN DRY LAKE/ MULESHOE VALLEY SIMULATION

LOCATION	AMOUNT PUMPED EACH YEAR (acre-ft/yr)					
	1982	1983	1984	1985	1986	1987
4N/64E-7dc [1]		251	968	282	341	183
2S/64E-19d	39.2	82.8	674.7	491.7	402.9	45
2S/64E-32d	39.2	82.8	674.7	491.7	402.9	45
1S/64E-16c	39.2	82.8	674.7	491.7	402.9	45
3S/64E-12ac	39.2	82.8	674.7	491.7	402.9	45
1N/64E-36c	39.2	82.8	674.7	491.7	402.9	45
TOTAL Dry Lake Valley[2]	196	414	3373	2458	2014	225
Muleshoe Valley[2]		251	968	282	341	183

1 T4N, R64E, Section 7dc

2 Preliminary water-demand estimates, U.S. Army Corps of Engineers

Preliminary estimates of the requirements were provided by the U.S. Army Corps of Engineers (March 1981). Table 4 shows the estimate for each year and shows how each annual requirement is divided among the six wells. In the model, the pumping rate varied from year to year, but the rate within each year was held constant and equal to the demand.

This pumping schedule was simulated by the model using a uniform transmissivity of 1300 ft^2/day (119 m^2/day) and a uniform specific yield of 0.05. Values of drawdown and recovery were obtained as a function of time throughout the valley-fill aquifer. Because all of the ground-water withdrawal came from storage with no reduced leakage to the carbonates, the drawdowns obtained from the model are overestimated during pumpage and underestimated during recovery.

4.4 AQUIFER IMPACTS

Table 5 represents data on drawdowns and on recovery at a distance of 1 mile (1.6 km) from each proposed MX production well. The drawdown data are the maximum for each well for each year of pumping. The maximum drawdown for the six years occurs generally during the last year and varies from 3.8 to 6.0 feet (1.2 to 1.8 m) depending upon the well location. The recovery data show that the residual drawdowns were 0.9 to 1.6 feet (0.3 to 0.5 m) after 30 years. However, most of the recovery took place during the first eight years; residual drawdowns were 1.6 to 2.7 feet (0.5 to 0.8 m) after 8.3 years of recovery.

TABLE 5 - DRAWDOWN AND RECOVERY ONE MILE FROM EACH PROPOSED MX PRODUCTION WELL

MAXIMUM DRAWDOWN (ft)

One Mile from Each Proposed Well

LOCATION	1982	1983	1984	1985	1986	1987
4N/64E-7dc	0	0.7	3.5	4.9	5.6	5.8
2S/64E-19d	0.1	0.4	2.5	4.6	6.0	6.0
2S/64E-32d	0.1	0.4	2.5	4.6	6.0	6.0
1S/64E-16c	0.1	0.3	1.9	3.3	4.1	3.8
3S/64E-12ac	0.1	0.4	2.3	4.0	5.2	5.1
1N/64E-36c	0.1	0.3	1.9	3.3	4.1	3.8

RECOVERY DATA

Residual Drawdowns 1 Mile from Wells

	after 1.9 years	after 8.3 years	after 30 years
4N/64E-7dc	4.7	2.7	1.2
2S/64E-19d	4.8	2.7	1.6
2S/64E-32d	4.8	2.7	1.6
1S/64E-16c	2.8	1.6	1.1
3S/64E-12ac	4.1	2.4	1.5
1N/64E-36c	2.8	1.6	0.9

The extent to which the drawdown and recovery data are conservative was estimated as a second part of the analysis. Primarily, the drawdown can be reduced and recovery increased by reduction of underflow. There is an unquantified effect of extractions from MX wells on the reduction of underflow with a resulting reduction in drawdown. However, the underflow occurs over a considerable area and it is unlikely that MX wells would significantly reduce underflow unless the wells were suitably located with respect to the discharge area and created sufficient drawdown to reduce the effective head for vertical leakage to the carbonates. Because these conditions are not likely to occur, there is little potential of effectively reducing the underflow.

Considering both parts of the analysis, the maximum drawdown and recovery from the simulation are reasonable and somewhat conservative. The maximum drawdown at a distance equal to or greater than 1 mile (1.6 km) from an MX well should be near to but slightly less than the values in Table 5; the recovery rates should be near to but slightly greater than values in the same table.

4.5 NEAR-WELL IMPACTS

To estimate the drawdown at simulated MX wells, a Thiem approximation was used to relate drawdown at a radius of 1 foot (0.3 m) to the values at the grid points used in the model. The results of the approximation are given in Table 6. They show a maximum drawdown of 118.22 feet (36.03 m) at the well in Muleshoe Valley

TABLE 6 - DRAWDOWN AND RECOVERY AT RADIUS OF ONE FOOT AT EACH PROPOSED MX PRODUCTION WELL

MAXIMUM DRAWDOWN (ft)

Radius of 1 Foot from Each Proposed Well

LOCATION	1982	1983	1984	1985	1986	1987
4N/64E-7dc	0	30.15	118.22	42.47	48.26	29.46
2S/64E-19d	4.71	10.26	81.94	64.97	55.93	13.56
2S/64E-32d	4.71	10.26	81.94	64.98	55.95	13.60
1S/64E-16c	4.71	10.24	81.80	64.60	55.28	12.67
3S/64E-12ac	4.71	10.25	81.76	64.76	55.58	13.11
1N/64E-36c	4.71	10.24	81.80	64.60	55.28	12.66

RECOVERY DATA

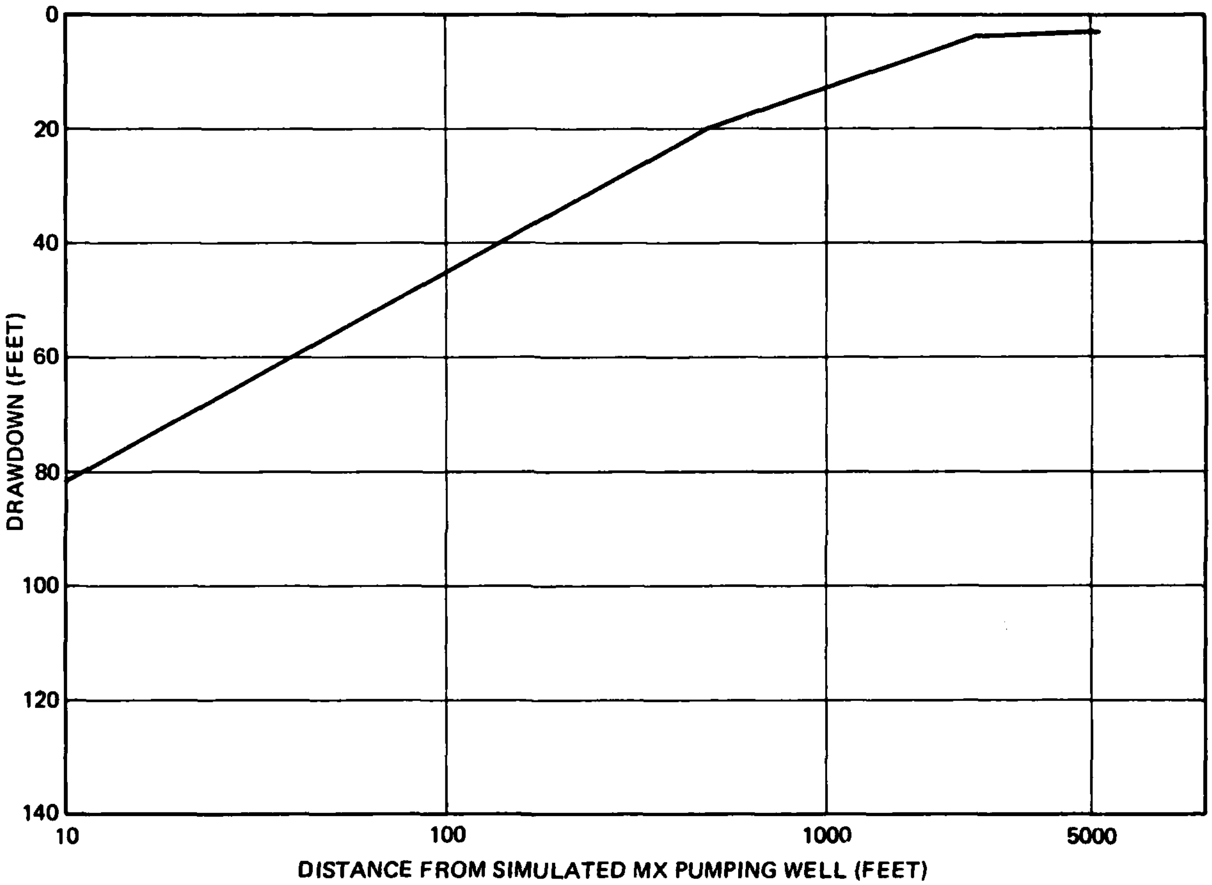
Residual Drawdowns at Radius of 1 Foot

	after 1.9 years	after 8.3 years	after 30 years
4N/64E-7dc	5.1	2.4	1.1
2S/64E-19d	4.9	2.6	1.6
2S/64E-32d	4.9	2.7	1.6
1S/64E-16c	3.8	1.7	1.1
3S/64E-12ac	4.4	2.3	1.4
1N/64E-36c	3.8	1.6	.9

(4N/64E-7dc) and a maximum drawdown of 81.94 feet (24.98 m) at the wells in Dry Lake Valley. The maximum drawdown values at the well occur during the year with the maximum pumping rate. This is in contrast to the maximum drawdown values at a distance of 1 mile (1.6 km) which occur at the end of the last year of pumping.

Data on recovery at the wells are also presented in Table 6. They were obtained directly from the regular output of the model without the facility of the Thiem approximation. The residual drawdowns correspond to the calculated elevation of the potentiometric surface at the centers of the finite-difference squares in which the wells are located. These drawdowns were 0.85 to 1.59 feet (0.26 to 0.48 m) at the MX wells after 30 years. However, most of the recovery occurred earlier because residual drawdowns were 1.61 to 2.65 (0.49 to 0.81 m) after 8.33 years of recovery.

Another indication of the near-well impacts is given by Figure 4 which is a distance-drawdown plot for the peak construction year of 1984. The plot should roughly approximate the effects near each of the five wells in Dry Lake Valley because uniform values of transmissivity and specific yield values were used throughout the valley, the pumping rates were the same, and Tables 5 and 6 indicate little difference in the drawdown at these five wells. The distance-drawdown plot indicates that the drawdown is less than 13 feet (4 m) at a distance of 1000 feet (305 m) from the well.



NOTE:

THE GRAPH REPRESENTS DRAWDOWN VERSUS LOGARITHM OF DISTANCE FROM A MX PUMPING WELL WITH A PUMPING RATE OF 674.7 ACRE-FT/YR (0.83 hm 3/YR; 418.3 gpm) THE PEAK CONSTRUCTION YEAR OF 1984.

Ertec The Earth Technology Corporation	MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO/AFRCE-MX

DRAWDOWN VERSUS LOGARITHM OF DISTANCE FROM MX PUMPING WELL

30 NOV 81 FIGURE 4

The estimates of near-well impacts are reasonable but conservative by the same arguments used in the discussion of aquifer impacts.

4.6 SUBSIDENCE POTENTIAL

Subsidence from ground-water withdrawal can result from decreased fluid pressure caused by lowering of the water table and, thereby, increased intergranular pressure. The literature shows that rates of subsidence range from approximately 0.01 to 0.5 feet (0.003 to 0.15 m) per 10-foot (3-m) drop in the water table, depending on the thickness and compressibility of the materials effected (Bouwer, 1977).

A thick sequence of unconsolidated or poorly consolidated sands and gravels, with interfingering fine-grained materials forming an interbedded aquifer-aquitard system, is a common depositional environment at subsidence sites. The sand and gravel aquifers are pumped, but a significant percentage of the section usually consists of highly compressible clays (Freeze and Cherry, 1979). These fine-grained materials exhibit the greatest amount of subsidence. A loose sand is relatively incompressible, whereas the compressibility of clay is much greater, particularly if the clay was previously uncompacted.

Based on test borings in the upper 200 feet (61 m) of the valley fill, the aquifer in Dry Lake Valley is composed of predominantly coarse-grained sediments consisting of sandy gravels, gravelly sands, silty sands, and clayey sands. These sediments occur as irregular, interfingering beds of varying thickness and

areal extent. Fine-grained sediments make up approximately 10 to 20 percent of the aquifer and are generally restricted to buried playa and lacustrine deposits along the valley axis. Local interfingering of coarse- and fine-grained deposits occur near playa margins. The coarse-grained sediments are generally dense to very dense, exhibit low compressibilities, and possess moderate to high shear strengths. The fine-grained materials exhibit low to moderate compressibilities and shear strengths (FN-TR-27-DL-I).

There should not be significant problems related to subsidence in Dry Lake Valley because 1) there is a low percentage of fine-grained sediments in the valley; 2) the sediments exhibit only low to moderate compressibilities; and 3) there is a relatively small change in fluid pressure which is limited to the areal extent of the effective pumping stress.

4.7 SUMMARY ASSESSMENT

The impacts of withdrawals from MX wells were estimated by superposition of the results from a simulation and from a simple analysis based on knowledge of the aquifer. It was found that:

1. The maximum drawdown of each of six proposed MX wells ranges from 82 to 118 feet (25 to 36 m). The residual drawdown 8.3 years after pumping for construction is less than 2.7 feet (0.8 m).

2. The maximum drawdown at a distance of 1 mile (0.6 km) from each of six proposed MX wells ranges from 3.8 to 6.0 feet (1.2 to 1.8 m). The residual drawdown 8.3 years after pumping for construction is less than 2.7 feet (0.8 m).

These estimates were reasonable but somewhat conservative. It is concluded that the drawdown effect of pumping from MX

wells is small to negligible. After the end of pumping for construction, the water table throughout the aquifer will return to within 3 feet (0.9 m) of the original elevation in 8.3 years and within 2 feet (0.6 m) in 30 years.

The potential for subsidence due to MX withdrawals was also examined. This potential was found to be small because of the limited number and thickness of the layers of fine-grained material and because the drawdown was generally too small to cause a significant change in pore pressure in the aquifer.

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